Galaxy Cluster IDCS 1426+3508 (z=1.75)

Image credit: NASA/CXC/M. Brodwin/STScI/JPL

MAPPING THE PATHWAYS OF GALAXY TRANSFORMATION

CATALINA ISLAND, JULY 31 -AUGUST 5, 2016

TRANSFORMING GALAXIES IN EXTREME ENVIRONMENTS

THE ERA OF STAR FORMATION AND AGN IN MASSIVE CLUSTERS AT z=1-2

Stacey Alberts JWST/MIRI Postdoc







Stacey Alberts





Stacey Alberts

WHEN IS THE ACTIVE EPOCH IN MASSIVE CLUSTERS?



SF IN CLUSTER CORES AT Z>1...



Evidence for less efficient quenching and field-like SF at z>~1.5 Rising fraction of (X-ray) AGN. also seen in MIR and radio selected AGN

0.5

 $L_{X,H} \ge 10^{43} \text{ erg/s}$

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 $[L_{X,H} > L_{X,H,tim}, M < M^*(z) + 1]$ 1000 1000 1000

Ł

0.0001

0.0

galpath16



1.0

Martini et al. 2013

Redshift



1.5



A DETAILED STUDY OF SF AND AGN IN Z=1-2 CLUSTERS

- ▶ 11 spectroscopicallyconfirmed clusters, M_{halo} ~ (1-4)x10¹⁴ M_☉
- Near-infrared (stellar mass selected) clusters
- deep Herschel/PACs Imaging

galpath16

AGN selected using full UV-MIR SED







Ma et al. 2016

2.0

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Alex Pope (UMass) Mark Brodwin (UMKC) Arjun Dey (NOAO) Peter Eisenhardt (Caltech) Anthony Gonzalez (UFlorida) Buell Jannuzi (Steward Obs.) **Greg Snyder (STScI)** Adam Stanford (UC Davis) Dan Stern (JPL/Caltech) Greg Zeimann (UPenn) Ryan Cybulski (UMass) Jim Geach (UHertfordshire) Sun Mi Chung (Ohio State) Audrey Galametz (Max-Planck) and the ISCS, MAGES, NDWFS, and SDWFS teams

Redshift



2.8

ears)

galpath16



IR-luminous (PACSdetected) Cluster Galaxies



SF VERSUS ENVIRONMENT

Alberts et al. 2016 <SFR> [M_☉yr⁻¹] 100 Inefficient ļ <SFR> [M_oyr⁻¹] or no quenching r h 100 at z>1.37! 1 < z < 1.371.37 < z < 1.75 ■ Lots of <SSFR> [Gyr⁻¹] 10 quenched (PACS 1.0 <SSFR> [Gyr⁻¹] undetected) galaxies at Ū-Φ z<1.37! 0.0 0.5 1.0 Projected Radius [M 0.1 0.0 2.0 0.5 1.5 1.0 IR-luminous (F Projected Radius [Mpc] (cumulative) detected) Cluster Galaxies **Mass-limited Cluster** Galaxies (stacked)

TIMESCALE FOR QUENCHING?

- no gradual decrease in PACSderived SFRs over ~0.6 Gyr
- stacked mass-limited samples show quenched pop at z<1.37
- cluster pops are red by z~1
- rapid quenching?
- missing SFG population? No, >~80% of SF accounted for by PACS



TIMESCALE FOR QUENCHING?

- SCUBA-2 submm continuum -> measure the ISM at z=1.75
- similar amount of gas to field galaxies
- average depletion times of ~0.3 Gyr
- no possibility of new gas accretion?
- soon: ALMA submm imaging of
 >100 cluster galaxies at z=1-2!!

Alberts et al. in prep







VARIATION AND HALO MASS



Alberts et al. 2016

galpath16



VARIATION AND HALO MASS



Alberts et al. 2016

galpath16



THE RISE OF AGN IN CLUSTERS

- X-ray/radio/MIR color AGN selections -> fraction of AGN increases in clusters with redshift
- SED fitting can find more complete AGN samples and composite objects (when X-ray is shallow...)



Measure AGN contribution to SED:

galpath16

Host dominated (<30%) Host composite (30-50%) AGN composite (50-70%) AGN dominated (>70%)

Chung et al. 2014



THE RISE OF AGN IN CLUSTERS



Host dominated (<30%) Host composite (30-50%) AGN composite (50-70%) AGN dominated (>70%)

Excess AGN fraction relative to the field in cluster cores at z>1.5

Parallels SF, related to quenching?

Environmental triggering... interactions, mergers?

CONCLUSIONS

- Clusters have field-like SF at z>~1.4, quenched populations by z~1
- short gas depletion timescales in z=1.75 cluster galaxies
 - Iarger sample with ALMA is coming soon!!
- variation between clusters in total SF, likely broad M_{halo} dependence



- AGN fraction in clusters at z>1.5 higher than field
 - environmental triggering,
 maybe related to quenching

